METHOD FOR RESOLVING PHOTOELECTRON

COUPLING IN STAGGERED CHARGE-COUPLED DEVICE

BACKGROUND OF THE INVENTION

5   Field of Invention

[0001]   The present invention relates to a method of resolving photoelectron

coupling.   More particularly, the present invention relates to a method of resolving

photoelectron coupling resulting from the operation of a staggered charge-coupled device

inside a scanner.

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Description of Related Art

[0002]   The optical sensors used by scanners can be divided into linear optical

sensors such as linear charge-coupled device (linear CCD) or subsequently developed

staggered optical sensors such as staggered charge-coupled device (staggered CCD).

15   [0003]   Fig. 1 is a schematic diagram showing the layout of a conventional

staggered charge-coupled device.   As shown in Fig. 1, each group of optical sensors in the

staggered CCD includes a pair of linear optical sensor arrays, often referred to as an odd

optical sensor array and an even optical sensor array.   These two rows of optical sensor

arrays have a line separation of M pixels.   Since a color scanner needs to process the three

20   primary colors, namely, red (R), green (G) and blue (B), there are three sets of optical

sensor groups.   Because the effect and method of operation for each optical sensor group

are identical, the operation of only one of the optical sensor groups- the one for processing

red color, is selected in the following illustration.

[0004]   When an even optical sensor array 124 processes the nth row of pixels of a document 100, the even pixels such as 2, 4, 6 and 8 are extracted.   Similarly, when the odd optical sensor array 122 processes the nth row of pixels, the odd pixels such as 1, 3, 5 and 7 are extracted.   After the odd optical sensor array 122 has finished extracting the nth row of

5   pixels, a processing circuit 146 outputs the extracted pixels of the two rows of optical sensor arrays in sequence.   Ultimately, the nth row of pixel data is output as a data series 102 for processing by a later stage circuit.

[0005]   However, as the odd optical sensor array 122 processes the nth row of pixels of the document 100 and because the odd and the even optical sensor arrays have a line

10   separation of M pixels, the even optical sensor array 124 will scan the $(n + M)^{th}$ row of pixels. If a scan document (the document 100 in Fig. 1) has darker and lighter regions as shown in Fig.1, the even optical sensor array 124 and the odd optical sensor array 122 will capture the $(n + M)^{th}$ row and the nth row of pixels during a scanning period t.   Since the even optical sensor array 124 scans a strip of the document in the lighter region, the number

15   of photoelectrons absorbed is larger.   Because of this, the odd optical sensor array 122 scanning the darker region of the document may absorb some of the photoelectrons captured by the even optical sensor array 124 and lead to a whitening of the darker region. In other words, the original black color region becomes a gray color region and hence the scanning operation produces undesirable image distortions.   Using the data series 102 as

20   an example, the sequential output pixel data will result in alternating gray, black, gray, black … instead of a uniform blackness with the identical brightness level of the original image.

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[0006]   On the other hand, because a portion of the image captured by the even

optical sensor array 124 is lost to the odd optical sensor array 122, the colors of the (n +

M)th row of pixels captured by the even optical sensor array 124 may also be distorted.

[0007]   Hence, the two rows of optical sensor arrays affect each other leading to a

partial coupling of the photoelectrons captured by the odd optical sensor array 122 and the

photoelectrons captured by the even optical sensor array 124.   Unless the staggered CCD

of a scanner is modified in some ways, color distortion is bound to be present.

[0008]   Conventionally, the only method of resolving the coupling in a staggered

CCD is to average out the first pixel brightness value and the second pixel brightness value

of the data series 102.   In other words, the brightness value of the even pixel and the odd

pixel are averaged to produce the color brightness value of the nth row of pixels.

[0009]   However, with this type of averaging, true color of the original color is

hidden.   In effect, the arrangement lowers the genuine color brightness level of even pixels

and raises the genuine color brightness level of the odd pixels.

SUMMARY OF THE INVENTION

[0010]   Accordingly, one object of the present invention is to provide a method of

resolving photoelectron coupling resulting from operating a staggered charge-coupled

device inside a scanner so that color distortion is minimized.   In addition, this method also

provides an effect means of calibrating color brightness level.

[0011]   To achieve these and other advantages and in accordance with the purpose

of the invention, as embodied and broadly described herein, the invention provides a

method of resolving photoelectron coupling of a staggered charge-coupled device.   During

a scanning period t, the amount of photoelectrons transferred between the batch of

photoelectrons captured by exposing an optical sensor array and the batch of photoelectrons

captured by exposing a neighboring optical sensor array is measured. Thereafter, the

amount of transferred photoelectrons is subtracted from the batch of photoelectrons

5 captured by exposing the optical sensor to find a more accurate number of photoelectrons

captured by the optical sensor in the period t for use as the brightness value.

[0012] Through a relatively simple computation, additional photoelectrons from a

neighboring optical sensor array captured by the optical sensor array or photoelectrons

originally captured by the optical sensor array but transferred to the neighboring optical

10 sensor array can be found so that a correct brightness value for an image is always secured.

[0013] It is to be understood that both the foregoing general description and the

following detailed description are exemplary, and are intended to provide further

explanation of the invention as claimed.

15 BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide a further understanding

of the invention, and are incorporated in and constitute a part of this specification. The

drawings illustrate embodiments of the invention and, together with the description, serve

to explain the principles of the invention. In the drawings,

20 [0014] Fig. 1 is a schematic diagram showing the layout of a conventional

staggered charge-coupled device;

[0015] Fig. 2 is a flow chart showing the steps for resolving photoelectron coupling

of the staggered charge-coupled device according to this invention; and

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[0016]   Fig. 3 is a flow chart showing the steps for finding the quantity of photoelectrons transferred between an odd optical sensor array and an even optical sensor array according to this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

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[0017]   Reference will now be made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

10   [0018]   Please refer to all three diagrams 1,2, and 3, a method of resolving photoelectron coupling resulting from the operation of a staggered charge-coupled device according to the first embodiment of the present invention is used to correct the problem of the staggered charge-coupled device (staggered CCD).

[0019]   As shown in Fig. 1, the staggered optical sensor includes at least a set of

15   optical sensor groups such as a set of optical sensor groups for detecting a primary color, red (R).   Furthermore, each optical sensor group includes an optical sensor array 122 and a neighboring optical sensor array 124.   In other words, each optical sensor group comprises of an odd optical sensor array 122 and an even optical sensor array 124 next to the odd optical sensor array 122.

20   [0020]   One major problem for the staggered CCD is that the two rows of optical sensors in each set of optical sensor group interact with each other.   The odd optical sensor array 122 couples with a portion of the photoelectrons captured by the even optical sensor array 124 during exposure leading to color distortion.   If the odd optical sensor

array is separated from the even optical sensor array by M pixels, the even optical sensor array 124 will start to capture the $(n + M)^{th}$ row of even pixels when the odd optical sensor array captures the nth row of odd pixels during a time interval t.   Ultimately, some mechanism must be implemented to re-calibrate the color brightness of the nth odd pixels

5   captured by the odd optical sensor array 122 and the $(n + M)^{th}$ even pixels captured by the even sensor array 124.

[0021]   The steps for resolving photoelectron coupling are listed out is Fig. 2.   In step s200, the amount of photoelectrons of odd pixels in the nth row captured by the odd optical sensor array 122 and the amount of photoelectrons of even pixels in the $(n + M)^{th}$

10   row captured by the even optical sensor array 124 due to exposure in a scanning time interval t are measured.   In step s202, the overall flow of photoelectrons between the captured photoelectrons inside the odd optical sensor array 122 and the captured photoelectrons inside the neighboring or even optical sensor array 124 are also measured.

[0022]   Assume N(n,t) is a function for the odd optical sensor array 122 to capture

15   the photoelectrons of odd pixels in the nth row during exposure in a scanning time interval t and N(n+M,t) is a function for the even optical sensor array 124 to capture the photoelectrons of even pixels in the $(n+M)^{th}$ row during exposure in the same scanning time interval t.

[0023]   The steps for measuring the overall amount of photoelectrons that moves

20   between the odd optical sensor array and the even optical sensor array are listed out in Fig. 3.   In step s300, the difference between the amount of photoelectrons captured by the odd optical sensor array 122 and the even optical sensor array 124 during a scanning time interval t is measured and is given by N(n+M,t) − N(n,t).

[0024]   In step s302, the exposure difference and a photoelectron mobility constant K are multiplied together so that the overall quantity of photoelectrons transferred between the odd optical sensor array 122 and the even optical sensor array 124 during a scanning time interval t is found in step s304 as $K*[N(n+M,t)-N(n,t)]$.

[0025]   In step s204 of Fig. 2, the quantity of photoelectrons transferred is subtracted from the amount of photoelectrons of odd pixel captured in the nth row   by the odd optical sensor array 122 during exposure to obtain a corrected quantity $N'(n,t)$ of photoelectrons of odd pixels in the nth row.   Hence, the value of $N'(n,t)$ is $N(n,t)-K*[N(n+M,t)-N(n,t)]$.   The photoelectron exposure value $N'(n,t)$ is used in step s206 to calibrate the color brightness of the nth odd pixels.

[0026]   The photoelectron mobility constant K is a percentage ratio of the photoelectrons captured by the odd optical sensor array 124 from the even optical sensor array 124 when the even optical sensor array 124 is exposed to capture photoelectrons.

[0027]   Since a portion of the photoelectrons of the $(n+M)^{th}$ row of even pixels captured by the even optical sensor array 124 is lost, the brightness level of the $(n+M)^{th}$ row of even pixels must be re-calibrated.   The method of calibration is similar to the method carried out for calibrating the photoelectrons of even pixels in the nth row captured by the odd optical sensor array 122.   To calibrate the quantity of photoelectrons captured by the even optical sensor array 124, if the row of pixels to be calibrated is the nth row of pixels, the quantity of photoelectrons captured by the odd optical sensor array is in the $(n-M)^{th}$ row of even pixel.   Accordingly, the value for calibrating the quantity of photoelectrons of even pixel in the nth row captured by the even optical sensor array 124 is $N'(n,t)=N(n,t)-K*[N(n-M,t)-N(n,t)]$, where the quantity of photoelectrons transferred is given by $K*[N(n-$

M,t)-N(n,t)] and K is still the photoelectron mobility constant. However, the even optical sensor array 124 loses a certain percentage of the captured photoelectrons.

[0028] In the aforementioned embodiment, the odd optical sensor array 122 captures the odd pixels in the darker region of a document 100 while the even optical sensor array 124 captures the even pixels in the lighter region of the document 100. Therefore, the even optical sensor array 124 will capture a quantity of photoelectrons higher than the odd optical sensor array 122. This may lead to the lost of a portion of the photoelectrons captured by the even optical sensor array 124 to the odd optical sensor array 122. Hence, the quantity of photoelectrons actually captured by the even optical sensor array 124 is lower than the quantity of photoelectrons that ought to be captured by the even optical sensor array 124. Conversely, the quantity of photoelectrons actually captured by the odd optical sensor array 122 is higher than the quantity of photoelectrons that ought to be captured by the odd optical sensor array 122.

[0029] On the contrary, the odd optical sensor array 122 may be set to capture the odd pixels in the lighter region of the document 100 while the even optical sensor array 124 may be set to capture the even pixels in the darker region of the document 100. In this case, a portion of the photoelectrons captured by the odd optical sensor array 122 will be lost to the even optical sensor array 124.

[0030] To resolve this problem, the formula used for computing the value N'(n,t) for calibrating the photoelectrons captured by the odd optical sensor array is the same formula for calibrating the value N'(n,t) photoelectrons captured by the odd optical sensor array in the aforementioned embodiment, namely, $N'(n,t) = N(n,t)-K*[N(n+M,t)-N(n,t)]$. However, the value of N(n,t) is higher than N(n+M,t) leading to the amount of

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photoelectron movement $K*[N(n+M,t)-N(n,t)]$ being a negative number. This further leads to the value $N'(n,t)$ of the quantity of calibrating photoelectrons of the odd pixels captured by the odd optical sensor array higher than the actual value $N(n,t)$ of the quantity of photoelectrons captured.

5   [0031]   The formula used for computing the value $N'(n,t)$ for calibrating the photoelectrons captured by the even optical sensor array is the same formula for calibrating the value $N'(n,t)$ photoelectrons captured by the odd optical sensor array in the aforementioned embodiment, namely, $N'(n,t) = N(n,t)-K*[N(n-M,t)-N(n,t)]$. However, the value of $N(n,t)$ is lower than $N(n-M,t)$ leading to the amount of photoelectron

10   movement $K*[N(n-M,t)-N(n,t)]$ being a positive number. This further leads to the value $N'(n,t)$ of the quantity of calibrating photoelectrons of the even pixels captured by the even optical sensor array lower than the actual value $N(n,t)$ of the quantity of photoelectrons captured.

[0032]   In the aforementioned method of finding the quantity of calibrating

15   photoelectrons for the odd and even pixels captured by the respective odd and even optical sensor arrays, the nth row of pixels is chosen as a reference position during scanning interval t for the odd and even optical sensor arrays. For example, to carry out a computation in a scanning time interval t for finding the quantity of calibrating photoelectrons in the nth row of odd pixels captured by the odd optical sensor array 122,

20   because the odd and even optical sensor array are separated by M pixels, the even optical sensor array 124 will scan the even pixel of the $(n+M)^{th}$ row during the a scanning interval t. To calculate the quantity of calibration photoelectrons of even pixels in the nth row captured by the even optical sensor array 124, because the odd and even optical sensor array are

separated by M pixels, the odd optical sensor array 122 will scan the odd pixel in the $(n-M)^{th}$ row during the scanning interval t.

[0033]   In the following embodiment, the nth row of pixels serves as a common scanning reference position for the two neighboring optical sensor arrays.   Assume the functional value of photoelectrons captured by the odd optical sensor array 122 is N(n,t) due to exposure and the functional value of photoelectrons captured by the even optical sensor array 124 is N(n+M,t) due to exposure.   According to the two functions N(n,t) and N(n+M,t), the formula for finding the quantity of calibration photoelectrons captured by the odd optical sensor array 122 is N'(n,t) = N(n,t)-K*[N(n+M,t)-N(n,t)].   Thereafter, the quantity of calibration photoelectrons N'(n,t) is used to correct the brightness value when the nth row of pixels is scanned by the odd optical sensor array 122.

[0034]   Similarly, according to the two functions N(n,t) and N(n+M,t), the formula for finding the quantity of calibration photoelectrons captured by the even optical sensor array 124 is N'(n+M,t) = N(n+M,t)-K*[N(n,t)-N(n+M,t)].   The quantity of calibration photoelectrons N'(n+M,t) is used to the correct brightness value when the $(n+M)^{th}$ row of pixels is scanned by the even optical sensor array 124.

[0035]   In conclusion, the present invention provides a method of resolving photoelectron coupling between the two rows of optical sensor arrays inside an optical sensor group of a staggered charge-coupled device.   Through relatively simple computation, additional photoelectrons from a neighboring optical sensor array captured by the optical sensor array or photoelectrons originally captured by the optical sensor array but transferred to a neighboring optical sensor array can be sorted out so that the brightness value for an image is corrected.   In other words, extra photoelectrons captured by the odd

optical sensor array during the scanning of the nth row of pixels can be removed and the quantity of photoelectrons lost from the even optical sensor array during the scanning of $(n+M)^{th}$ row of pixels can be replenished so that brightness value of the image is suitably compensated.

5   [0036]   It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention.   In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.

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